

WHAT IS CLAIMED IS:

1. A control apparatus for a multi-cylinder engine capable of performing compression ignition combustion, or selecting either the compression ignition combustion or spark ignition combustion, comprising:

a cylinder-specific combustion state estimating means for estimating a combustion state for each cylinder; and

a combustion state control means for controlling the combustion state for each cylinder;

wherein the combustion state control means controls, during an engine operation in a compression ignition combustion mode, the combustion state for each cylinder based on the combustion state estimated by the cylinder-specific combustion state estimating means during the engine operation in the compression ignition combustion mode.

wherein the cylinder-specific combustion state estimating means estimates the combustion state based on a signal provided by a cylinder pressure sensor disposed in at least one cylinder of the multi-cylinder engine.

2. The control apparatus for the multi-cylinder engine according to claim 1, wherein the cylinder-specific combustion state estimating means estimates a peak value of a cylinder pressure of each cylinder and peak timing of the cylinder pressure and the combustion state control means controls so that the peak value of the cylinder pressure of each cylinder falls within a predetermined range and/or the peak timing falls within a predetermined period of time after piston top dead center.

3. The control apparatus for the multi-cylinder engine according to claim 1, wherein the combustion state control means controls other combustion states including a mode changeover between spark ignition combustion and

compression ignition combustion based on the operating condition of the multi-cylinder engine, the operating condition of a piece of equipment mounted with the multi-cylinder engine, an intention of a user of the equipment and the like.

4. The control apparatus for the multi-cylinder engine according to claim 1, wherein the cylinder-specific combustion state estimating means estimates the combustion state based on a vibration signal provided by a vibration detecting sensor disposed in a cylinder block or a cylinder head of the multi-cylinder engine.

5. The control apparatus for the multi-cylinder engine according to claim 1, wherein the combustion state control means controls at least one of a variable valve mechanism that varies an amount of internal EGR by changing at least one of the valve timing and an amount of valve lift of an intake valve and an exhaust valve, a fuel injection mechanism that directly or indirectly injects fuel into a combustion chamber of the multi-cylinder engine, and a transmission that transmits output shaft torque of the multi-cylinder engine to a power train mechanism of a vehicle through adjusting a gear ratio.

6. The control apparatus for the multi-cylinder engine according to claim 5, wherein the combustion state control means controls the variable valve mechanism so as to increase a minus overlap amount, thereby increasing the amount of internal EGR when it is estimated that the peak value of cylinder pressure of at least one of the plurality of cylinders is lower than a predetermined value, or the peak timing of cylinder pressure is retarded in relation to predetermined timing, based on the estimation made by the cylinder-specific combustion state estimating means.

7. The control apparatus for the multi-cylinder engine according to claim 5, wherein the combustion state control means controls the variable valve mechanism so as to decrease the minus overlap amount, thereby decreasing the amount of internal EGR when it is estimated that the peak value of cylinder pressure of at least one of the plurality of cylinders is higher than a predetermined value, or the peak timing of cylinder pressure is advanced in

relation to predetermined timing, based on the estimation made by the cylinder-specific combustion state estimating means.

8. The control apparatus for the multi-cylinder engine according to claim 5, wherein the combustion state control means controls the transmission so as to change the gear ratio, thereby decreasing an engine speed when it is estimated that the peak value of cylinder pressure of at least one of the plurality of cylinders is lower than a predetermined value, or the peak timing of cylinder pressure is retarded in relation to predetermined timing, based on the estimation made by the cylinder-specific combustion state estimating means.

9. The control apparatus for the multi-cylinder engine according to claim 5, wherein the combustion state control means controls the transmission so as to change the gear ratio, thereby increasing the engine speed when it is estimated that the peak value of cylinder pressure of at least one of the plurality of cylinders is higher than the predetermined value, or the peak timing of cylinder pressure is advanced in relation to the predetermined timing, based on the estimation made by the cylinder-specific combustion state estimating means.

10. The control apparatus for the multi-cylinder engine according to claim 8, wherein the combustion state control means increases an amount of fuel supplied from the fuel injection mechanism to each cylinder per one cycle.

11. The control apparatus for the multi-cylinder engine according to claim 8, wherein the combustion state control means decreases an amount of fuel supplied from the fuel injection mechanism to each cylinder per one cycle.

12. The control apparatus for the multi-cylinder engine according to claim 6, wherein the fuel injection mechanism is a type that injects fuel directly into the cylinder; and the combustion state control means provides control so as to effect at least one fuel injection during the minus overlap period by the variable valve mechanism during the compression ignition combustion mode and, if the cylinder-specific combustion state estimating means estimates that the cylinder pressure peak value of at least one cylinder out of the plurality

of cylinders is lower than the predetermined value, or the cylinder pressure peak timing of at least one of the plurality of cylinders is retarded in relation to the predetermined timing, controls the fuel injection mechanism to increase the amount of fuel injected therefrom into the cylinder during the minus overlap period.

13. The control apparatus for the multi-cylinder engine according to claim 7, wherein the fuel injection mechanism is a type that injects fuel directly into the cylinder; and the combustion state control means provides control so as to effect at least one fuel injection during the minus overlap period by the variable valve mechanism during the compression ignition combustion mode and, if the cylinder-specific combustion state estimating means estimates that the cylinder pressure peak value of at least one cylinder out of the plurality of cylinders is higher than the predetermined value, or the cylinder pressure peak timing of at least one of the plurality of cylinders is advanced in relation to the predetermined timing, controls the fuel injection mechanism to decrease the amount of fuel injected therefrom into the cylinder during the minus overlap period.

14. The control apparatus for the multi-cylinder engine according to any of claim 1, wherein, if the cylinder-specific combustion state estimating means estimates that the cylinder pressure peak value of at least one cylinder out of the plurality of cylinders falls outside the predetermined range, or the cylinder pressure peak timing of at least one of the plurality of cylinders falls outside the predetermined period of time, the control apparatus inhibits the compression ignition combustion mode for the multi-cylinder engine, or switches the operating mode to the spark ignition combustion mode.

15. The control apparatus for the multi-cylinder engine according to claim 14, wherein the control apparatus warns the user of the equipment mounted with the multi-cylinder engine, if the compression ignition combustion mode is inhibited.

16. A control method for a that performs compression ignition combustion control or provides control so as to select either the compression ignition combustion or spark ignition combustion, comprising the steps of:

estimating, during an engine operation in the compression ignition combustion mode, a combustion state for each cylinder during the engine operation in the compression ignition combustion mode; and

controlling the combustion state of each cylinder based on the estimated combustion state for each cylinder multi-cylinder engine wherein the cylinder pressure of each cylinder represents a value that is the result of analyzing a vibration frequency detected of the multi-cylinder engine.

17. The control method for the multi-cylinder engine according to claim 16, wherein other combustion states including a mode changeover between spark ignition combustion and compression ignition combustion is controlled based on the operating condition of the multi-cylinder engine, the operating condition of a piece of equipment mounted with the multi-cylinder engine, an intention of a user of the equipment and the like.

18. The control method for the multi-cylinder engine according to claim 16, wherein the cylinder pressure of each cylinder represents a value obtained by a cylinder pressure sensor disposed in at least one of the plurality of cylinders of the multi-cylinder engine.